# Evolved Stars at PTI: Size, Shape, Mass and Atmospheric Structure

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## Science Objectives and Summary

One of the last observational problems in stellar atmospheres is the detailed study of the surface structure of a star. The lowest-order measurable parameter of surface structure, the the overall size, is necessary for the determination of the stellar effective temperature. In the H-R diagram, the coolest region is the least well constrained by observation. K - M luminosity class I - III stars are common and potentially useful in galactic structure studies, as distance indicators, so that their properties ought to be well understood. Significant steps to delineate the effective temperature scale for cool stars have been made by Ridgway et al. (1980), DiBenedetto & Rabbia (1987), DiBenedetto & Ferluga (1990) and DiBenedetto (1993), using observations made primarily at near-infrared wavelengths. Recent interferometric efforts by Dyck et al. (1996a, 1996b, 1998) and Perrin et al. (1998) have led into the current effort at PTI (van Belle et al. 1998).

## Available Targets

By comparing the Catalog of Infrared Observations (Gezari et al. 1993) with information available from SIMBAD, a large database may be constructed on candidate stars which includes spectral type and broad-band photometry from B to M. Angular sizes may be estimated for these objects by one of two methods:

- Invoking simple relationship between bolometric flux and apparent K magnitude (Dyck, Lockwood & Capps 1974), combined with an assumed effective temperature from MK spectral type (Dyck et al. 1996b, 1998) can deliver a estimate on angular size.
- Cross-correlation of the database with the Hipparcos database to obtain those stars for which a parallax has been measured; the resultant distance, in combination with linear size (as assumed from MK spectral type; Allen 1973), an angular size may be estimated.

Stars were limited to: those that were brighter than $m_K < 4.5$, $m_V < 10$, $0^\circ < \delta < 52^\circ$, 0.9 mas < $\theta_{EST}$ < 4.3 mas (the smaller lower limit reflects the anticipated increase in resolution due to use of the H band). The following four classes of evolved stars (apart from Miras and other objects addressed in other adovcacy reports) are evidence in the database (numbers in parentheses indicate total number of potential science targets):

- KM Giants (490) – The 'bread and butter' of infrared angular sizes, these stars are plentiful in number and distribution. PTI measured the sizes of roughly 70 of these stars last observing season (van Belle et al. 1998); a continued investigation of these objects is recommended as an extension of the existing database, and as logical exploitation of PTI's high throughput.
- BAFG Giant Stars (68) – PTI's large baseline and high sensitivity make these smaller, hotter giants realistic targets that are both smaller and dimmer at K. Much of the previous interferometric work has concentrated on the K and M giants only out of necessity.
- Supergiant Stars (91) – As with the earlier type giants, these objects tend to be smaller in angular size due to their typically greater distances. Again, PTI can contribute much to this poorly sampled set.
- Carbon Stars (50) – The sum total of previous angular size measurements for these objects in the literature is 23 (Dyck et al. 1996b, Richichi et al. 1998); with a modest amount of effort, a number equal to or greater than that sum could be easily obtained at PTI.

## Specific Investigations

**Angular Size: Radius, Temperature and Mass**. Combined with bolometric flux (calculated from existing broad-band photometry) and distance (from Hipparcos parallaxes), effective temperatures and linear radii may be established from angular sizes obtained at PTI. Furthermore, in conjunction with measures of surface gravity (see Tautvaišienė & Lazauskaitė 1993 for a sample discussion of obtaining $g$ independent of prior assumptions of $M$), linear radii can lead to values for stellar mass. Preliminary research into use of this data indicates the potential for unraveling some of the degeneracies found in empirical determinations of temperature and radius as a function of V-K and K-[12] colors.

**Absorption Features**. Even though the spectral resolution of PTI is quite crude, it still could be usefully employed in investigating dependencies of visibility upon wavelength. Specifically, the $^{12}CO(2,0)$ absorption band at 2.29-2.30 μm (Wallace & Hinkle 1996) is a feature that grows in strength towards the later spectral types (Ramierz et al. 1997); detection of a visibility dependence for later spectral type giants and carbon stars could lead to intriguing interpretations regarding stellar atmospheric structure and mechanisms of mass loss.

**Shape (Departures from Spherical Symmetry)**. The two baselines now available to PTI will allow for adequate *(u,v)* plane coverage to do some simple parametric modelling of stellar shapes. Specifically, characterizations of stellar asphericity can finally make hamburger of the spherical cow; stellar atmosphere modellers quake at the thought (Hauschildt 1997).

**Limb Darkening**. PTI's ability to do crude spectroscopy at H and K could quite easily lead to parameterizations of limb darkening for the largest stars in the sample. Inversion of the limb darkening-atmospheric structure relationship can lead to insights into the nature of stellar atmospheres (Pierce & Waddell 1961), although this has proven to be insanely difficult.

## Observing Strategy

Two nights of observing per object are all that are required for each object, once per night per object. Given an expected throughput of 7 stars per hour, with a calibrator-target-target queue, and 6 hours of observing per night, 42 stars may be observed per night, of which 28 will be target stars. Thus, the expectation is that 28 stars can be observed from the samples noted above every two days. Five 1-week observing campaigns spread over the observing season has the potential to resolve roughly 200 stars, assuming a third of the nights are lost to weather, and a third of the throughput lost to instrumentation difficulties. Concentration of source selection upon the poorly sampled sets above (all except the KM giants) could result in substantial datasets to draw upon for publications.

## Collaboration

I'll spearhead this scientific investigation of staggering importance; partners in crime are being actively solicited. I expect to continue to receive contributions from Ben on bolometric flux calcuations and general programming; Michelle's expertise on these lumpy masses of molecular ash-upchucking goo will be well spent on interpreting the results; and I will continue to extract as much general wisdom on these stars from my collaborators at USNO, Mel Dyck and Bob Thompson.

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